

A New Look At Gravitational Coupling Constant And The Dark Energy Problem

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In this paper, we establish that the solution to the dark energy problem is connected to the cutoff Ultraviolet (UV) scale M_{pl} manifesting itself as linearly independent infrared sectors of the effective theory of gravity interacting with QCD fields. We work in the combined frameworks of finite temperature - density corrections and effective quantum field theory (as low energy quantum gravity). We strongly suggest that the failure to reproduce the exact observed value of dark energy (ρ_Λ) from the framework of Veneziano ghost theory of QCD is intimately linked to the unverifiable ad hoc assumption that conditions the gravitational coupling constant to be unity ($C_{grav} = 1$). A close perusal of the Minkowski vacuum structure reveals that $C_{grav} \neq 1$. We compute the value of C_{grav} from the Bose-Einstein distribution function. With $C_{grav} = 1.797 \times 10^{-1}$ coupled with the value of vacuum energy estimated from the Veneziano ghost theory of QCD , we reproduce the observed value of ρ_Λ to be $\rho_\Lambda \approx C_{grav} (3.6 \times 10^{-3} eV)^4 \approx (2.3 \times 10^{-3} eV)^4$. An important prediction of these combined frameworks (made manifest by the application of standard box-quantization procedure to the UV scale M_{pl}) states that there are $\approx 10^{122}$ linearly independent “subuniverses” representing the linearly independent infrared sectors of the effective theory of gravity interacting with QCD fields. A direct consequence of this is that our subuniverse is embedded on a non-trivial manifold M (such as a torus group $T^{10^{122}} = T^1 \times \dots \times T^1$) with different linear sizes.

Keywords: Bose-Einstein distribution function, Veneziano ghost theory of QCD, Dark energy.

I. INTRODUCTION

One of the most flummoxing problems in modern physics that kept scientists at alert and has been hotly debated since 1929, is the realization of the expansion of the universe, established when Edwin Hubble published his revolutionary paper. Astronomical observations and study of universe, in the past few decades, strongly invalidated astronomers’ view point that the universe was entirely composed of “baryonic matter”. The latest conformation of the accelerating universe [1–5] endorsed the fact that the universe is infused with an unknown form of energy density (dubbed as dark energy (ρ_Λ)) which makes up for about 75% of the total energy density of the universe. It is this 75% mysterious ρ_Λ , which conditions our three-dimensional spatial curvature to be zero, that is responsible for the acceleration of the universe. This discovery provided the first direct evidence that ρ_Λ is non-zero, with $\rho_\Lambda \approx (2.3 \times 10^{-3} eV)^4$ [6, 7].

However, the theoretical expectations for the ρ_Λ exceed observational limits by some 120 orders of magnitude [8]. This huge discrepancy between theory and observation, hitherto, constitutes a serious problem for theoretical physics community. In fact, Steven Weinberg puts it more succinctly by saying that the small non-zero value of ρ_Λ is “a bone in the throat of theoretical physics”. Considering this huge discrepancy may unshroud something fundamental, yet to be unveiled, about the hidden nature of the universe. This paper is one of such attempts.

The most elegant and comprehensible endeavour in order to solve this problem, in our view, was put forward by F. R. Urban and A. R. Zhitnitsky [6]. These authors approached the problem from the angle of the effective theory of gravity interacting with standard model fields by using the solution of the $U(1)$ problem as put forward by G. Veneziano and E. Witten [9, 10]. In this framework, the basic problem of why the dark energy is 120 orders of magnitude smaller than its Planck scale M_{planck}^4 , is replaced by fundamentally different questions: “(i) What is the relevant scale which enters the effective theory of gravitation? (ii) How does this scale appear in the effective quantum field theory for gravity?” In their view, this effective scale has nothing to do with the cutoff ultraviolet (UV) scale M_{planck} : the appropriate effective scale must emerge as a result of a subtraction at which some infrared (IR) scale enters the physics. They completely turned the problem on its head!

Though their attempt being cognizant, yet it fails to reproduce, exactly, the measured value of ρ_Λ [11]. We observe here that their assumption $g \equiv c = C_{QCD} \times C_{grav} = 1$ is debatable, since it is valid only for C_{QCD} but not for C_{grav} , as proved in this paper. Here g is the Minkowski metric in vacuum, C_{QCD} is the Quantum Chromodynamic (QCD) coupling constant, and C_{grav} is the gravitational coupling constant.

From Ref.[7], the value of C_{grav} was wrongly computed to be $C_{grav} = 0.0588$ (which is approximately one-third of the value we proved in our calculation) but for obvious reason the authors neglected this value and used a position dependent Minkowski metric distance $g(x^2)$ instead. They computed $g(x^2)$ to be $g(x^2) = 1/6.25$. For no clear reason, they approximated the value of $g(x^2)$ to $g(x^2) \approx 1/6$ by truncating 0.25 from their original value of $g(x^2)$. This approach is totally unacceptable in the

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field of computational cosmology where every minuscule value counts.

In this paper, we have proved the value of C_{grav} to an order of magnitude less than one i.e. 1.797×10^{-1} ; this leads towards the exact measured [11] value of ρ_Λ . In order to get this value, we have used finite temperature and density (*FTD*) correction technique. Here, the *FTD* background acts as highly energetic medium (M_{plank}^4) controlling the particle propagation. Our basic guiding idea is that the finite temperature field theory (*FTFT*), similar to the physics of superconductivity (quantum field theory at $T = 0$), is linked to the infrared sector of the effective theory of gravity interacting with standard model fields, specifically with *QCD* fields [6]. In this case, the statistical background effects are incorporated in propagators through the Bose-Einstein distribution function [12, 13]: it is worth noting that the Bose-Einstein distribution function is the mathematical tool for understanding the essential feature of the theory of superconductivity [13]. The general attribute of a successful theory of superconductivity is the existence of degenerate vacuum/broken symmetry mechanism. A characteristic feature of such a theory is the possible existence of “unphysical” zero-mass bosons which tend to preserve the underlying symmetry of the theory. The masslessness of these singularities is protected in the limit $q \rightarrow 0$. This means that it should cost no energy to create a Yang-Mills quantum at $q = 0$ and thus the mass is zero [14]. In the preceding Ref. the Goldstone-Salam-Weinberg theorem is valid for a zero-mass pole, which is protected. That pole is not physical and is purely gauge, hence unphysical. This is precisely the highly celebrated Veneziano ghost [6], which is analogous to the Kogut-Susskind (*KS*) ghost in the Schwinger model (*distinctive unphysical degree of freedom which is massless and can propagate to arbitrary large distances*).

It is imperative to note that this set of unphysical massless bosons tends to transform as a basis for a representation of a compact Lie group [13] thereby, forming a compact manifold. We do not make any specific assumptions on the topological nature of the manifold; we only assume that there is at least one Minkowski metric distance that defines a general covariance of comoving coordinates [4] with size $L_M = 2 \times \text{Euclidean metric distance}$.

In the next section, we derive the finite temperature and density relation for the Veneziano ghosts by using Bose-Einstein distribution function. It should be noted here that Veneziano ghosts are treated as unphysical massless bosons due to the fact that they both have the same propagator $(+ig_{\mu\nu}/q^2)$ [6]: the propagator for unphysical massless boson is obtained from $(+ (2\pi)^4 ie^2 g_{\mu\nu}/q^2) \langle \phi \rangle^2$ [13].

II. VENEZIANO-GHOST DENSITY

From Fermi-Dirac and Bose-Einstein distribution functions, we have

$$n_r = \frac{g_r}{e^{\alpha + \beta \varepsilon_r} \pm 1} \quad (1)$$

The positive sign applies to fermions and the negative to bosons. g_r is the degenerate parameter, α is the coefficient of expansion of the boson gas inside the volume (V), β is the Lagrange undetermined multiplier, n_r and ε_r are the numbers of particles and the energy of the r -th state respectively. The value of α for boson gas at a given temperature is determined by the normalization condition [15]

$$N = \sum_r \frac{g_r}{e^{\alpha + \beta \varepsilon_r} - 1} \quad (2)$$

This sum can be converted into an integral, because for a particle in a box, the states of the system have been found to be very close together i.e. ($\Delta \varepsilon_{vac} \equiv d\varepsilon \rightarrow 0$). Using the density of single-particle states function, *Eq.(2)* reduces to

$$N = \int_0^\infty \frac{D(\varepsilon) d\varepsilon}{e^{\alpha + \beta \varepsilon} - 1} \quad (3)$$

Where $D(\varepsilon) d\varepsilon$ is the number of allowed states in the energy range ε to $\varepsilon + d\varepsilon$ and ε is the energy of the single-particle states. Using the density of states as a function of energy, we have [15]

$$D(\varepsilon) d\varepsilon = \frac{4\pi V}{h^3} 2m\varepsilon \left(\frac{m}{p} \right) d\varepsilon$$

with $p = \sqrt{2m\varepsilon}$

$$D(\varepsilon) d\varepsilon = 2\pi V \left(\frac{2m}{h^2} \right)^{3/2} \varepsilon^{1/2} d\varepsilon \quad (4)$$

Putting *Eq.(4)* into *Eq.(3)*, we get

$$N = 2\pi V \left(\frac{2m}{h^2} \right)^{3/2} \int_0^\infty \frac{\varepsilon^{1/2} d\varepsilon}{e^{\alpha + \beta \varepsilon} - 1} \quad (5)$$

Where m is the mass of boson and h is the Planck constant. $\alpha = \beta\mu$ and $\beta = 1/kT$. μ is the chemical potential, k is the Boltzmann constant and T is temperature. Since there is no restriction on the total number of bosons, the chemical potential is always equals to zero. Thus *Eq.(5)* reads as:

$$N = 2\pi V \left(\frac{2m}{h^2} \right)^{3/2} \int_0^\infty \frac{\varepsilon^{1/2} d\varepsilon}{e^{\varepsilon/kT} - 1} \quad (6)$$

By using standard integral

$$\int_0^\infty \frac{x^{z-1} dx}{e^x - 1} = \zeta(z) \Gamma(z)$$

where $\zeta(z)$ is the Riemann zeta function and $\Gamma(z)$ is the gamma function. Eq.(6) takes the form

$$N = 2.61V \left(\frac{2\pi mkT}{h^2} \right)^{3/2}$$

Let $n_{gv} = N/V$

$$n_{gv} = 2.61 \left(\frac{2\pi mkT}{h^2} \right)^{3/2} \quad (7)$$

Recall that $m = \Delta\varepsilon_{vac}/c^2$ and the average kinetic energy of gas in three-dimensional space is given by $\Delta\varepsilon_{vac} = \frac{3kT}{2}$. Thus Eq.(7) becomes

$$n_{gv} = \left(\frac{(2.61)(3\pi)^{3/2} k^3}{(hc)^3} \right) T^3$$

Define

$$\begin{aligned} \xi &\equiv \left(\frac{(2.61)(3\pi)^{3/2} k^3}{(hc)^3} \right) \\ &= 2.522 \times 10^7 (mk)^{-3} \end{aligned}$$

Hence, the Veneziano-ghost density(n_{gv}) can be re-expressed in more elegant form as:

$$n_{gv} = \xi T^3 \quad (8)$$

Eq.(8) is the required result for the finite temperature and density relation for the Veneziano ghost(s).

III. GRAVITATIONAL COUPLING CONSTANT FROM VENEZIANO-GHOST DENSITY

The principle of general covariance tells us that the energy-momentum tensor in the vacuum must take the form

$$\langle 0 | \hat{T}_{\mu\nu} | 0 \rangle = T_{\mu\nu}^{vac} = g \langle \rho \rangle \quad (9)$$

Here $\langle \rho \rangle$ has the dimension of energy density and g describes a real gravitational field [5]. Thus Eq.(9) can be written as

$$\langle 0 | \hat{T}_{\mu\nu} | 0 \rangle = g (\Delta\varepsilon_{vac})^4 \quad (10)$$

Where “ g ” in Ref.[6, 7], is defined as $g \equiv c = C_{QCD} \times C_{grav}$. Therefore, Eq.(10) can be written as

$$\langle 0 | \hat{T}_{\mu\nu} | 0 \rangle = C_{QCD} \times C_{grav} \times (\Delta\varepsilon_{vac})^4$$

Where, $C_{QCD} = 1$ as quoted by [7], and references within, thus

$$\langle 0 | \hat{T}_{\mu\nu} | 0 \rangle = C_{grav} \times (\Delta\varepsilon_{vac})^4 \quad (11)$$

Now, the energy density can be written as

$$\rho_{vac} = \frac{\Delta\varepsilon_{vac}}{V} = V^{-1} \times \Delta\varepsilon_{vac} \quad (12)$$

Eq.(12) is justified by the standard box-quantization procedure [5]. By comparing Eq.(12) with Eq.(8), we get

$$\rho_{vac} = n_{gv} \times \Delta\varepsilon_{vac} \quad (13)$$

With $n_{gv} \equiv V^{-1}$, From the average kinetic energy for gas in three-dimensional space, we have $T = 2\Delta\varepsilon_{vac}/3k$. Hence Eq.(8) becomes

$$n_{gv} = \frac{8\xi (\Delta\varepsilon_{vac})^3}{27k^3} \quad (14)$$

Putting the value of n_{gv} in Eq.(13), we get

$$\rho_{vac} = \frac{8\xi (\Delta\varepsilon_{vac})^4}{27k^3} \quad (15)$$

Eq.(15) represents the energy density of a vacuum state.

The natural demand of the Lorentz invariance of the vacuum state is bedecked in the structure of (effective) quantum field theory in Minkowski space-time geometry [5, 16]. Hence, if $|0\rangle$ is a vacuum state in a reference frame S and $|0\rangle$ refers to the same vacuum state observed from a reference frame S' , which moves with uniform velocity relative to S , then the quantum expression for Lorentz invariance of the vacuum state reads

$$|0\rangle = u(L) |0\rangle = |0\rangle \quad (16)$$

Where $u(L)$ is the unitary transformation (acting on the quantum state $|0\rangle$) corresponding to a Lorentz transformation L . All the physical properties that can be extracted from this vacuum state, such as the value of energy density, should also remain invariant under Lorentz transformations [5]. If the Lorentz transformation is initiated by ρ_{vac} , then $2 \times \rho_{vac}$ is needed for a unitary transformation to take place. The logic behind this assumption is simple: if ρ_{vac} defines the Lorentz invariant length (L) (Euclidean metric distance) of $|0\rangle$, then the Lorentz transformation from $|0\rangle$ to $|0\rangle$ (with continuous excitation) requires $2 \times \rho_{vac}$: $|0\rangle \xrightarrow{2 \times \rho_{vac}} |0\rangle$. This leads to the principle of general covariance as apriori stated in the introduction [5]. Thus,

$$\langle 0 | \hat{T}_{\mu\nu} | 0 \rangle = 2 \times \rho_{vac} = \frac{16\xi (\Delta\varepsilon_{vac})^4}{27k^3} \quad (17)$$

Eq.(17) is also justified by the standard box-quantization procedure [5]. Now by combining Eq.(11) and Eq.(17), we have

$$C_{grav} = \frac{16\xi}{27k^3} = 2.336 \times 10^{19} (m.eV)^{-3}$$

As $1m = 5.07 \times 10^{15} GeV^{-1}$. This leads to

$$C_{grav} = 1.797 \times 10^{-1} \quad (18)$$

which is the required gravitational coupling constant.

IV. DARK ENERGY FROM THE VENEZIANO-GHOST: A REVIEW

The major ingredient of standard Witten-Veneziano resolution of $U(1)$ problem is the existence of topological susceptibility χ . In Ref.[6], it has been proved that the deviation in χ , i.e. $\Delta\chi$, represents the vacuum energy density (*dark energy*). We review this result by making use of Eq.(9) and resolve the inherent hitch in this approach with the help of Eq.(18). Thus from Eq.(9) we have,

$$i \int dx \langle 0 | \hat{T}_{\mu\nu} | 0 \rangle = i \int dx T_{\mu\nu}^{vac} \quad (19)$$

By using the standard Witten-Veneziano relations

$$\hat{T}_{\mu\nu} \equiv T \{ Q(x), Q(0) \}$$

Where

$$Q \equiv \frac{\alpha_s}{16\pi} \epsilon^{\mu\nu\rho\sigma} G_{\mu\nu}^a G_{\rho\sigma}^a \equiv \frac{\alpha_s}{8\pi} G_{\mu\nu}^a \tilde{G}^{\mu\nu a} \equiv \partial_\mu K^\mu$$

And

$$K^\mu \equiv \frac{\Gamma^2}{16\pi^2} \epsilon^{\mu\nu\lambda\sigma} A_\nu^a \left(\partial_\lambda A_\sigma^a + \frac{\Gamma}{3} f^{abc} A_\lambda^b A_\sigma^c \right) \quad (20)$$

Where A_μ^a are the conventional QCD color gluon fields and Q is the topological charge density, and $\alpha_s = \frac{\Gamma^2}{4\pi}$. Thus we have

$$i \int dx \langle 0 | T \{ Q(x), Q(0) \} | 0 \rangle = i \int dx T_{\mu\nu}^{vac}$$

$$\lim_{q \rightarrow 0} i \int dx e^{iqx} \langle 0 | T \{ Q(x), Q(0) \} | 0 \rangle = \lim_{q \rightarrow 0} i \int dx e^{iqx} T_{\mu\nu}^{vac} \quad (21)$$

Let

$$\lim_{q \rightarrow 0} i \int dx e^{iqx} T_{\mu\nu}^{vac} = \chi$$

Hence Eq.(21) becomes

$$\chi = \lim_{q \rightarrow 0} i \int dx e^{iqx} \langle 0 | T \{ Q(x), Q(0) \} | 0 \rangle$$

And

$$\Delta\chi = \Delta \left[\lim_{q \rightarrow 0} i \int dx e^{iqx} \langle 0 | T \{ Q(x), Q(0) \} | 0 \rangle \right] \quad (22)$$

Using $\Delta = \frac{c(H/m_\eta)}{\left[\lim_{q \rightarrow 0} i \int dx e^{iqx} \langle 0 | T \{ Q(x), Q(0) \} | 0 \rangle \right]}$ and $-\left[\lambda_{YM}^2 (q^2 - m_0^2) / (q^2 - m_0^2 - \frac{\lambda_\eta^2}{N_c}) \right]$ from Ref.[6], Eq.(22) can be written as

$$\Delta\chi = -c \left(\frac{2H}{m_\eta} \right) \cdot \frac{\lambda_{YM}^2 (q^2 - m_0^2)}{(q^2 - m_0^2 - \frac{\lambda_\eta^2}{N_c})} \quad (23)$$

The standard Witten-Veneziano solution of $U(1)$ problem is based on the well-established assumption (confirmed by various lattice computations) that χ does not vanish, despite the fact that Q is a total derivative $Q \equiv \partial_\mu K^\mu$. This suggests that there is an unphysical pole at $q = 0$ in the correlation function of K^μ , similar to KS ghost in the Schwinger model [6]. Thus Eq.(23) becomes

$$\Delta\chi = -c \left(\frac{2H}{m_\eta} \right) \cdot \frac{\lambda_{YM}^2 m_0^2}{m_\eta^2} \quad (24)$$

where $m_\eta^2 = m_0^2 + \frac{\lambda_\eta^2}{N_c}$ is the mass of physical η field and the reason for a factor of 2 in Eq.(24) follows from the principle of general covariance as we have already established. Using Witten-Veneziano relation $4\lambda_{YM}^2 = f_\pi^2 m_\eta^2$ and chiral condensate $m_0^2 f_\pi^2 = -4m_q \langle \bar{q}q \rangle$, Eq.(24) can be written as

$$\Delta\chi = c \left(\frac{2H}{m_\eta} \right) |m_q \langle \bar{q}q \rangle| \quad (25)$$

where H is Hubble constant and m_q is the mass of a single light quark. From Ref.[6] $c \left(\frac{2H}{m_\eta} \right) |m_q \langle \bar{q}q \rangle| \approx c (3.6 \times 10^{-3} eV)^4$ leads to

$$\Delta\chi \approx c (3.6 \times 10^{-3} eV)^4 \quad (26)$$

By using $c = C_{QCD} \times C_{grav} \approx C_{grav}$ from [7] and reference within, Eq.(26) can be written as

$$\Delta\chi \approx C_{grav} (3.6 \times 10^{-3} eV)^4 \quad (27)$$

Comparison of Eq.(18) with Eq.(27) gives

$$\rho_\Lambda \equiv \Delta\chi \approx (2.3 \times 10^{-3} eV)^4 \quad (28)$$

Eq.(28) is the measured value of ρ_Λ that is responsible for the acceleration of the universe.

Using Planck scale M_{Pl}^4 as the cutoff correction, Eq.(8) becomes

$$n_{gv}^{planck} = 7 \times 10^{103} m^{-3} \quad (29)$$

From the standard box-quantization procedure [5], we have

$$2 \times \rho_\Lambda^{total} = \frac{1}{V} \sum_k \hbar \omega_k \quad (30)$$

By imposing Lorentz invariance of vacuum state formalism on Eq.(30), we have

$$2 \times \rho_\Lambda^{total} = \frac{1}{V} n \hbar \omega = n [n_{gv} \times \Delta\varepsilon_{vac}] \quad (31)$$

Where $n_{gv} \equiv \frac{1}{V}$ and $\Delta\varepsilon_{vac} \equiv \hbar \omega$. Note that Eq.(31) reduces to Eq.(17) for $n = 1$, therefore Eq.(31) can be rewritten for Planck scale cutoff correction (where Planck series of energy ($n \hbar \omega$) is taken to be the Planck energy (E_{Pl})):

$$n [n_{gv} \times \Delta\varepsilon_{vac}] = n_{gv}^{Planck} \times E_{Pl} \quad (32)$$

From Eqs.(13), (14), (15), (17) and (28), we have

$$n \left[\frac{8\xi (\Delta\varepsilon_{vac})^4}{27k^3} \right] = n_{gv}^{Planck} \times E_{Pl} \quad (33)$$

Where $\rho_{vac} = \rho_\Lambda/2$ is the energy density of each infrared sector. Eq.(33) shows how cutoff UV scale M_{Pl}^4 manifests itself as linearly independent infrared sectors of the effective theory of gravity interacting with QCD fields.

By combining Eqs.(28), (29) and (33) we have

$$n = 4 \times 10^{122} \approx 10^{122} \quad (34)$$

Where $n_{gv}^{Planck} \times E_{Pl} = M_{Pl}^4 = 1.4 \times 10^{113} J/m^3$. Thus Eq.(34) suggests that there are $\approx 10^{122}$ (degenerate) vacuum states. These vacuum states (n -torus) are called “subuniverses or multiverse” [17–21]. An n -torus is an example of n -dimensional compact manifold or a compact Abelian Lie group $U(1)$. In this sense, it is a product of n circles i.e $T^n = S^1 \times S^1 \times \dots \times S^1 = T^1 \times T^1 \times \dots \times T^1$ [22–24]. In this paper, n circles, which are the elements of $U(1)$ group, represent n linearly independent infrared sectors or the unphysical massless gauge bosons dubbed as Veneziano ghosts.

It is important to notice that the existence of non-vanishing and linearly independent infrared sectors of the effective theory of gravity interacting with QCD fields is parametrically proportional to the Planck cut-off energy. Therefore, our simple extension of Veneziano ghost theory of QCD to accommodate FTFT has striking consequences: it predicts, accurately, the value of C_{grav} , which leads towards the 100% consistency between theory and experimental value of ρ_Λ . As an offshoot, it fortifies the idea of multiverse and paints a new picture of quantum cosmological paradigm.

V. SUMMARY AND CONCLUSION

The computational analysis of the dark energy problem from the combined frameworks of finite temperature-density correction technique and the Veneziano ghost theory of QCD conditions FTD background to behave like a reservoir for the infrared sectors of the effective theory of gravity interacting with QCD fields. These infrared sectors (unphysical massless bosons) transform as a basis for a representation of a compact manifold. This is analogous to the process of quantizing on manifold M (such as a torus group $T^n = T^1 \times \dots \times T^1 = T^{10^{122}}$), in which all the submanifolds (tori) are linearly independent of each other. This means that an “observer” trapped in

one of such tori would think his torus is the whole Universe. An important prediction of this is that the vacuum energy $\Delta\epsilon_{vac}$ owes its existence to the degenerate nature of vacuum (or to the asymmetric nature of the universe). The effect of this is a direct consequence of the embedding of our subuniverse on a non-trivial manifold M with (minuscule) different linear sizes.

The main result of the present study is that the effective scales obviously have something to do with the cutoff Ultraviolet (UV) scale M_{Pl} . Based on the standard box-quantization procedure, the UV scale M_{Pl} is a collection of infrared (IR) scales. Undoubtedly, the relevant effective scales appear as a result of energy differences (subtractions) at which the IR scales enter the physics of UV scale M_{Pl} . It is therefore impossible to compute the value of ρ_Λ without putting into consideration the statistical effect of the UV scale M_{Pl} which

manifests itself through the existence of the linearly independent IR sectors of the effective theory of quantum field theory (QFT): this is the “stone” that confirms the interrelationship between $FTFT$ and the theory of superconductivity (QFT at $T = 0$).

Thus, if you buy the idea of Lorentz invariance of vacuum state formalism or the degenerate vacuum mechanism, then $\sim 10^{122}$ subuniverses come as free gifts!

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